

## EFFECTS OF RESPONSE-INDEPENDENT NEGATIVE REINFORCERS ON NEGATIVELY REINFORCED KEY PECKING

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Previous research has shown that presenting response-independent positive reinforcers reduces the response rate of an operant maintained by positive reinforcement. The present experiment investigated a similar effect using shock-free time as a negative reinforcer. Brief shocks were delivered in the presence of a distinctive stimulus, and pigeon's key pecks were reinforced by the occasional presentation of a 2-minute shock-free period. Extra 2-minute shock-free periods were added independently of behavior. For each of three pigeons, response rate during shock-on periods declined with added shock-free periods; the more frequently the extra shock-free periods occurred the greater the decline in response rate. This outcome is predicted by extending the Law of Effect to include negative reinforcement.

*Key words:* law of effect, alternative reinforcement, negative reinforcement, contraprepared responses, key pecking, pigeons

If total behavior, expressed as a rate, is constant, then the relative rate of a specific behavior maintained by a particular reinforcing consequence often occurs at a rate that equals the ratio between total reinforcement and the reinforcing consequence produced by that specific behavior. Herrnstein (1970) expressed this formally:

$$B_1 = \frac{KR_1}{R_1 + R_0}; \quad (1)$$

in which  $B_1$  is the absolute response rate for a given behavior,  $R_1$  is the reinforcement rate produced by  $B_1$ , and  $R_0$  is the reinforcement produced (or simply present in the experimental situation) by all sources other than that produced by  $B_1$ .  $K$  is an asymptotic rate that is approached as  $R_1$  increases (or  $R_0$  decreases) without limit.

Equation 1 predicts that adding response-independent reinforcement will decrease the rate of an operant maintained by an unchanged reinforcement schedule. Rachlin and

Baum (1972) confirmed this prediction with positive reinforcers. Adding reinforcers from any of several sources decreased the rate of pigeon's key-pecking response maintained by a constant rate of grain reinforcement. The suppressive effect of added reinforcement was the same when the reinforcers were unsignaled and when signaled in various ways.

Several observations suggested the suppressive effect was not due to adventitious response-reinforcer contingencies and was not due to the reinforcement of incompatible behaviors. If added reinforcement functioned to adventitiously reinforce responding, responding would have been expected to increase, but it decreased instead. Because added noncontingent reinforcement had the same effect when it was delayed with respect to responding and when it was not delayed, the decrease in response rate appeared not to be a by-product of the strengthening of incompatible behavior. The pigeons apparently discriminated between response-dependent reinforcement and response-independent reinforcement on the basis of the dependency alone.

Positive and negative reinforcement can be viewed from within the same conceptual framework (Baum, 1973a). In both cases, a response produces a transition to a higher valued situation. With positive reinforcement, this transition is typically to a situation in which food is present (e.g., when the food hopper is up)

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or to a situation correlated with food (e.g., the terminal link of a concurrent chain schedule). With negative reinforcement, the transition is typically to a situation in which there is a lowered shock frequency (e.g., Herrnstein & Hineline, 1966) or to a situation in which shock is absent for some specified interval (e.g., Sidman, 1953).

The full extent to which negative reinforcement parallels positive reinforcement is yet to be determined. Adding noncontingent negative reinforcers should reduce the rate of a negatively reinforced response just as adding positive reinforcers reduces positively reinforced responding (Rachlin & Baum, 1972). The present experiment tested this prediction by intermittently reinforcing pigeon's key pecks with 2-min of shock-free time, and then adding extra 2-min shock-free periods independently of behavior and observing the resulting changes in the rate of the negatively reinforced keypeck. Rate of key pecking was expected to decrease when noncontingent shock-free periods were added.

## METHOD

### *Subjects*

Three White Carneaux pigeons from the Palmetto Pigeon farm, South Carolina, were maintained at 80% of their free-feed body weight throughout the experiment. The subjects (AS-1, AS-2, and B-40) had served in other experiments on negative reinforcement.

### *Apparatus*

A standard conditioning chamber (BRS-LVE) with two translucent response keys was housed in a sound attenuating box. The keys were centered 20.3 cm apart 25 cm from the floor of the chamber and required a force of at least .44N. Only the left key was used here. Shock of .3 sec duration was delivered via a mercury commutator, attached to the top of the experimental chamber, through stainless steel electrodes surgically implanted around the pigeons' pubis bones (Azrin, 1959). Intensity was controlled by a variable AC transformer which was in series with a 10k-ohm resistor. Subjects AS-1 and B-40 received 60-volt shocks and AS-2 90-volt shocks throughout the experiment. These intensities were selected on the basis of the subject's behavior

and were set to produce reliable key pecking without extreme disruption. A masking noise of approximately 80 dB was on throughout the experimental session. A probability generator helped provide the interval schedules.

### *Procedure*

Because all three subjects were previously trained to avoid electric shock by pecking a key, they were introduced directly to the baseline condition. The original training procedures for these subjects were similar to those reported by Lewis, Lewin, Stoyak, and Muehlheisen (1974).

In the baseline condition, shocks were delivered at 3-sec intervals (FT 3-sec) unless a peck occurred on the right, red key. Pecks were reinforced on a random-interval 45-sec (RI 45-sec) schedule; i.e., a peck was reinforced, on an average of once every 45 sec, with a 2-min period of shock-free time. During the no-shock period the right key turned white. At the end of the 2-min period, the key became red and the FT 3-sec shock schedule was reinstated.

The four experimental conditions differed from the baseline condition only in that noncontingent 2-min shock-free periods were superimposed on the basic RI 45-sec schedule. At all times the RI 45-sec schedule was in effect during the shock period. Sometimes, however, shock-free periods were imposed even though an effective response had not been emitted. Thus, shock-free periods were sometimes provided as a result of responding on the RI 45-sec schedule and sometimes as a result of the response-independent (RT) schedule. The nominal values of the response-independent schedules were RT 8-sec, RT 19-sec, RT 37-sec, and RT 81-sec.

The RI and RT schedules were generated by sampling random probability devices every two seconds. If an "extra" shock-free period was to be delivered, it occurred immediately. If an "extra" shock-free period occurred while a contingent shock-free period was available but not yet delivered, the contingent shock-free period was cancelled.

Table 1 gives the order of the conditions and the number of sessions each bird was exposed to each condition. In Table 1, RI and RT values are shown as mean reinforcement deliveries per min for the last 10 sessions in each condition.

Table 1

Reinforcers (2-min shock-free periods) per min during the shock-on periods for contingent (RI) and noncontingent (RT) schedules. Last column gives proportion of total responses in shock-on period that were emitted in the first second following shock.

Subject	Nominal RI Value	Obtained RI Value	RT Value	Order	Sessions	Proportion of responses in first second following shock
AS-1	1.33	1.32	—	1	18	
	1.33	0.72	2.25	2	30	
	1.33	0.86	1.06	3	30	
	1.33	1.17	0.65	4	30	
	1.33	0.02	6.90	5	45	.600
	1.33	0.86	1.29	6	30	.772
AS-2	1.33	1.24	—	1	29	
	1.33	1.00	0.42	2	45	
	1.33	1.10	3.11	3	45	
	1.33	0.64	6.58	4	45	.963
	1.33	1.11	1.38	5	45	.974
	1.33	1.29	—	6	45	.909
B-40	1.33	1.27	—	1	21	
	1.33	1.18	1.63	2	30	
	1.33	1.25	0.74	3	30	
	1.33	0.56	7.35	4	30	.536
	1.33	1.27	1.40	5	30	.647
	1.33	1.22	2.75	6	30	.624
	1.33	1.22	0.70	7	30	.700

## RESULTS

Table 2

Means, ranges, and standard deviations of response rates for the last 10 sessions in each condition, given in order of administration.

Nominal condition (in sec)	Mean	Range	Standard deviation
<i>AS-1</i>			
RI 45	8.00	2.97-11.68	2.42
RI 45 RT 19	2.58	0.69- 4.91	1.33
RI 45 RT 37	4.91	2.72- 6.51	1.09
RI 45 RT 81	7.42	5.76- 9.22	1.16
RI 45 RT 8	0.20	0.00- 0.56	.20
RI 45 RT 37	6.24	4.39- 7.67	1.15
<i>AS-2</i>			
RI 45	41.93	29.30-57.10	9.32
RI 45 RT 81	25.99	16.52-33.70	5.32
RI 45 RT 19	19.68	16.26-23.80	2.36
RI 45 RT 8	12.02	6.45-18.23	4.30
RI 45 RT 37	22.06	17.06-27.60	3.03
RI 45	25.81	21.90-31.00	2.84
<i>B-40</i>			
RI 45	31.76	23.80-37.10	4.01
RI 45 RT 37	26.14	22.50-29.90	2.97
RI 45 RT 81	18.72	15.06-21.60	2.36
RI 45 RT 8	4.28	1.98- 6.98	1.72
RI 45 RT 37	27.19	25.19-31.50	2.50
RI 45 RT 19	20.50	16.80-24.80	2.76
RI 45 RT 81	28.49	20.60-34.40	3.82

Figure 1 shows the mean response rate for the last 10 sessions in each condition for each subject. Table 2 gives the ranges and standard deviations for these sessions. These data reflect responding only in the shock component of each schedule, during which the RI contingency was in effect. Response rates in the shock-free components were near zero for each subject. It can be seen that, with the exception of a single data point for each animal, the response rate declined as the frequency of free reinforcers (shock-free time) increased. For each subject, the highest mean response rate was found in the baseline condition and the lowest in the condition with the highest noncontingent reinforcement rate.

The distribution of responses throughout the 3-sec shock-shock interval did not seem to be reliably correlated with the experimental condition in effect. The far right-hand column in Table 1 gives these data for the sessions in which this information was available. In these sessions, a record was kept of the number of responses emitted, in half-second intervals, during the period initiated by shock de-

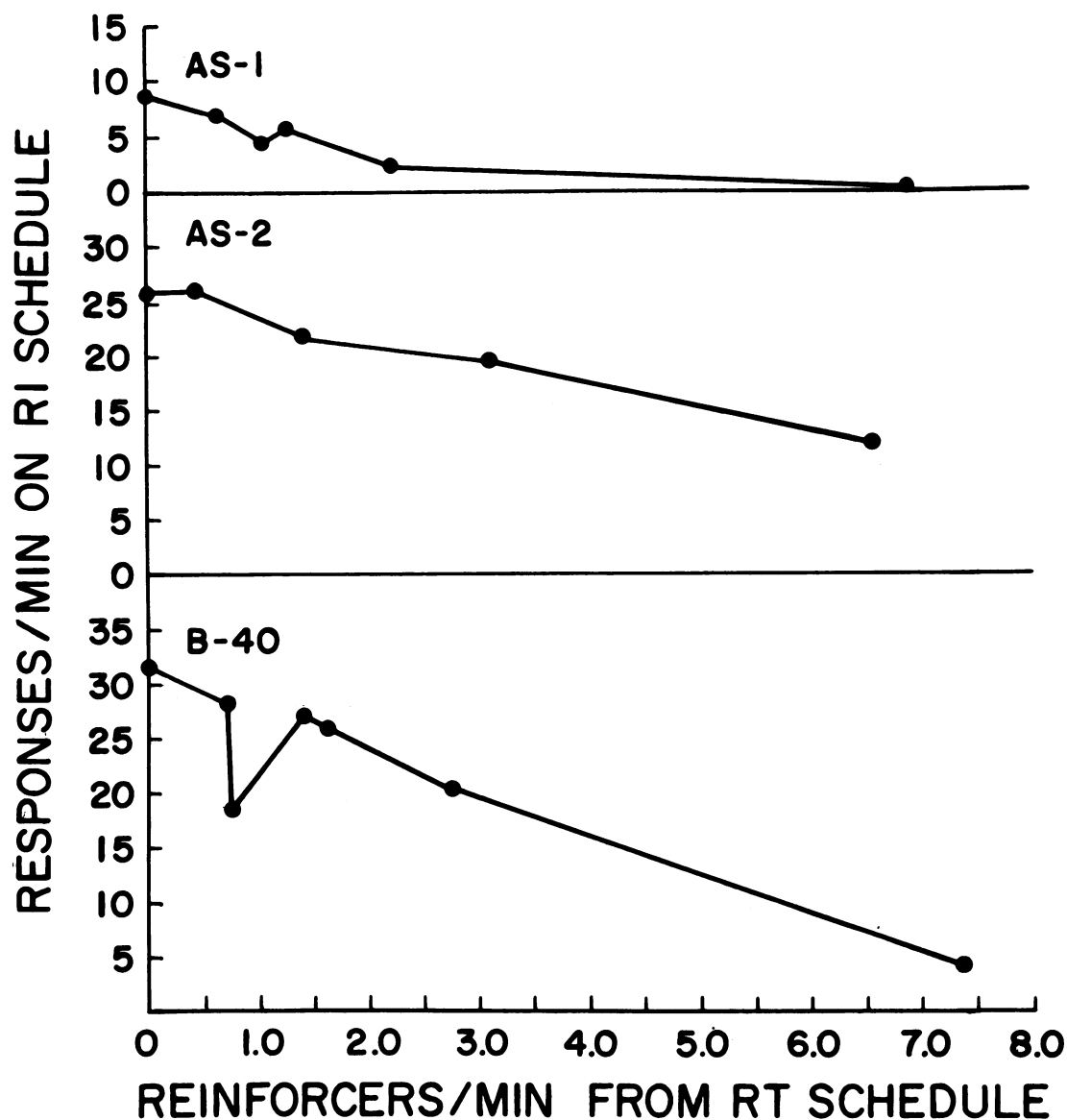


Fig. 1. Key pecks per min on a negative reinforcement schedule as a function of added response-independent negative reinforcers. Key pecks occasionally produced 2-min shock-free periods (RI schedule). In addition, extra 2-min shock-free periods were added according to a random time (RT) schedule.

livery and terminated by the next shock, at which time another interval began. It can be seen that in no case were fewer than half the responses emitted during the first second, indicating that the responding may have been shock-induced.

#### DISCUSSION

Adding "extra" shock-free periods decreased responding on a negative reinforcement sched-

ule; the more shock-free periods added, the more the response rate decreased.

It has been previously shown that time allocated to a schedule will increase as a function of the frequency of negative reinforcement (Baum, 1973b). The present experiment extends the symmetry between positive and negative reinforcement to the case in which response-dependent negative reinforcement is held constant while response-independent negative reinforcement is varied. As in Rachlin

and Baum's (1972) experiment on the suppressive effects of free food, the addition of noncontingent reinforcers (in this case, of noncontingent negative reinforcers) appeared to exert its effect on the basis of the fact that no programmed contingency existed between responding and the delivery of a reinforcer.

It should be pointed out that at least one alternative explanation is possible. The addition of free reinforcers may have adventitiously reinforced pausing during shock periods, subsequently reducing the response rate. In fact, this is a possible mechanism for the suppressive effects of free food, although Rachlin and Baum (1972) included controls that reduced the possibility of this interpretation. We did not, and adventitious reinforcement cannot be ruled out in the present experiment. However, an increased rate of noncontingent reinforcement should increase the probability that reinforcement delivery would follow responding as well and therefore should, in some cases, increase response rate through the adventitious reinforcement of responding. A superstitious-reinforcement interpretation is, therefore, ambiguous in its prediction as to the direction of change (free reinforcement could adventitiously reinforce responding or pausing). Because the direction of change was consistent and because our results are consistent with those of Rachlin and Baum, it seems unlikely that a superstitious-reinforcement interpretation is the most plausible one.

Most of the responding observed in this experiment was post-shock responding; i.e., it occurred within .5 sec or within 1.0 sec after the delivery of shock. In this respect, the data are not parallel to those found on positive reinforcement procedures. Post-shock keypecking, like post-shock responding in general, is poorly understood (see Gardner & Lewis, 1977). Post-shock key pecking is, however, negatively reinforced behavior; if the shock-free period is omitted, the key pecking stops (Lewis et al., 1974).

The pattern of keypecking observed in the present experiment parallels the pattern reported by Rachlin and Baum (1972). Adding negative reinforcement from alternative sources decreased pecking reinforced by negative reinforcement in the present experiment. If we assume that reinforcement is a positive-valued situation transition (Baum, 1973), both the present findings and Rachlin and Baum's

are predicted by Baum's (1973a) extension of Herrnstein's (1970) matching equation:

$$B_1 = K \frac{V_1}{V_1 + mV_E + V_0}, \quad (2)$$

where  $B_1$  is the absolute response rate on the contingent key,  $K$  is an asymptotic rate approached as the proportion of reinforcers on the contingent key approaches 1.0,  $V_1$  is the reinforcement value for pecking the contingent key,  $V_E$  is the value added by noncontingent (but experimenter-arranged) reinforcers, and  $V_0$  is the value endemic to or simply present in the experimental situation. The term  $m$  is a measure of the interaction between  $V_E$  and  $V_1$  which is assumed to be 1.0 for concurrent schedules.

The calculation of the  $K$  and  $V_0$  terms for each bird in Figure 3 was carried out as follows. Absolute response rate  $B_1$ , response contingent reinforcement  $V_1$ , and response independent reinforcement rate  $V_E$  were determined directly. The basic equation was  $B_1 = V_1/(V_1 + V_E + V_0)$ . The reciprocal of both sides was plotted, giving  $1/B_1 = (V_1/KV_1) + (V_E/KV_1) + (V_0/KV_1)$ . Rearranging terms, we have  $1/B_1 = (1/K) + (V_E/KV_1) + (V_0/KV_1)$  or  $1/B_1 = (1/K) + (V_0/KV_1) + (1/KV_1) + V_E$ . This equation is that of the straight line  $1/B_1 = \text{intercept} + \text{slope } V_E$ , in which the intercept is equal to  $1/K + V_0/KV_1$  and the slope is  $1/KV_1$ . Since the slope and intercept can be determined by a least-squares regression equation, we can solve for  $K$  by  $K = V_1/\text{slope}$ ; recall that  $V_1$  was held constant. Similarly, using the obtained value of  $K$  permits a unique solution for  $V_0$  by substituting the known values for  $K$  and  $V_1$  in the equation for the intercept.

Figure 2 shows response rate as a function of the proportion of contingent shock-free periods to total shock-free periods. In other words, rate is plotted as a function of  $V_1/(V_1 + V_E)$ . The proportion of variance accounted for ( $r^2$ ) by the best-fit regression line relating  $B_1$  to  $V_1/(V_1 + V_E)$  is in the lower right-corner of each figure. It can be seen that, although response rate is predicted with some accuracy by the regression equation, the lines do not intercept near the origin (zero response rate) for any of the subjects.

Figure 3 shows the obtained response rate as a function of the proportion of presumed total value received from keypecking. Rate is

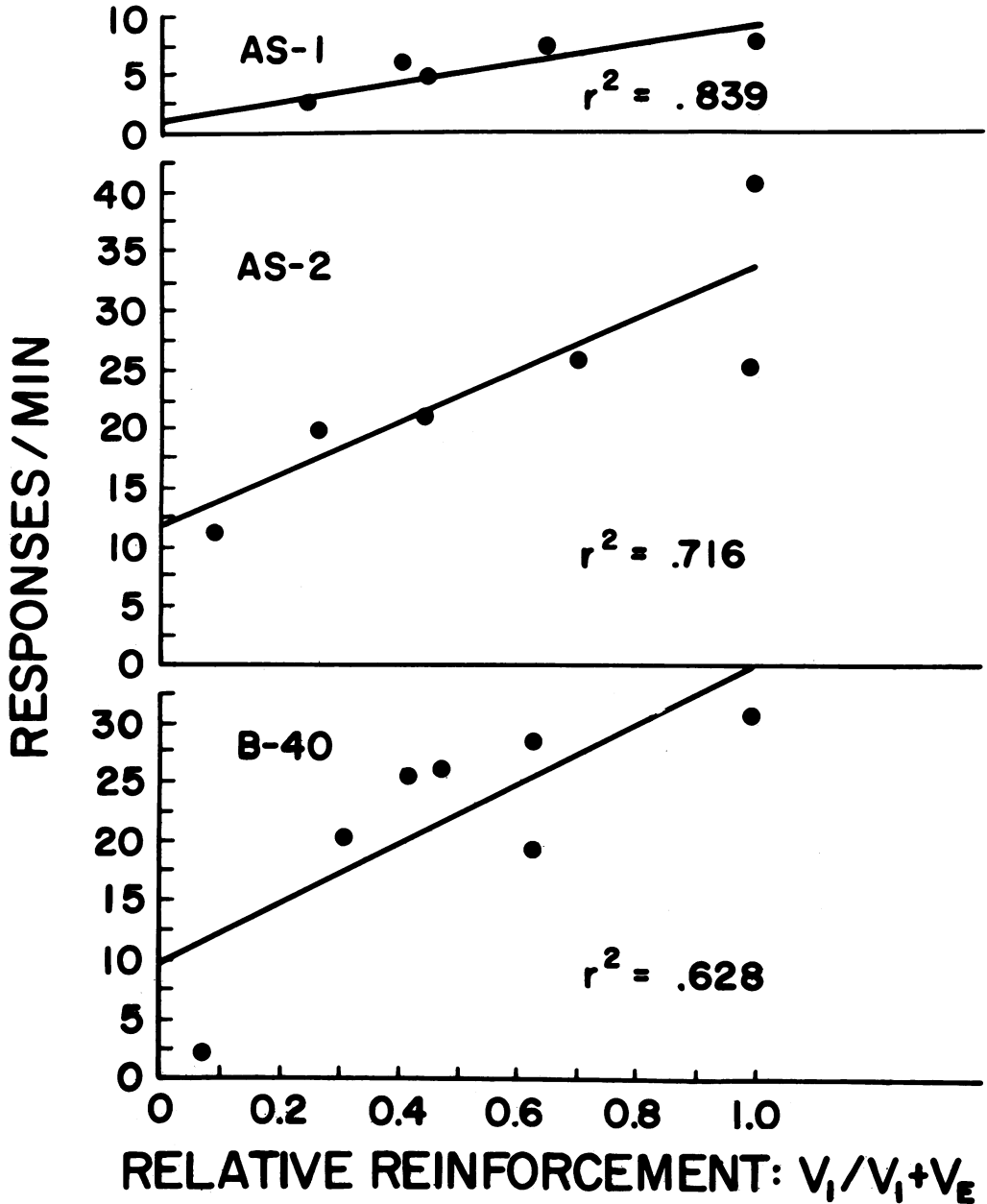


Fig. 2. Key pecks per min as a function of the proportion of reinforcement due to pecking (from the random-interval schedule) to reinforcement from both the random-interval and random-time schedules.

shown as a function of  $V_1/(V_1 + V_E + V_0)$ , rather than of  $V_1/(V_1 + V_E)$  as was the case in Figure 2, and overall response rate is seen to be correlated with the proportion of reinforcers received for responding, as predicted by Equation 2. Values for  $K$  and  $V_0$  are indicated in each figure, and the proportion of variance accounted for ( $r^2$ ) by the estimated proportion of total value (i.e.,  $V_1/V_1 + V_E +$

$V_0$ ) contingent on responding is given in the lower right of each figure. The proportion of variance accounted for by the best-fit regression lines are high and quite similar for each subject in both figures 2 and 3.

The regression lines in Figure 3, unlike those for Figure 2, do not intercept above the origin, which implies that a nonzero response rate would be observed even if no reinforcers were

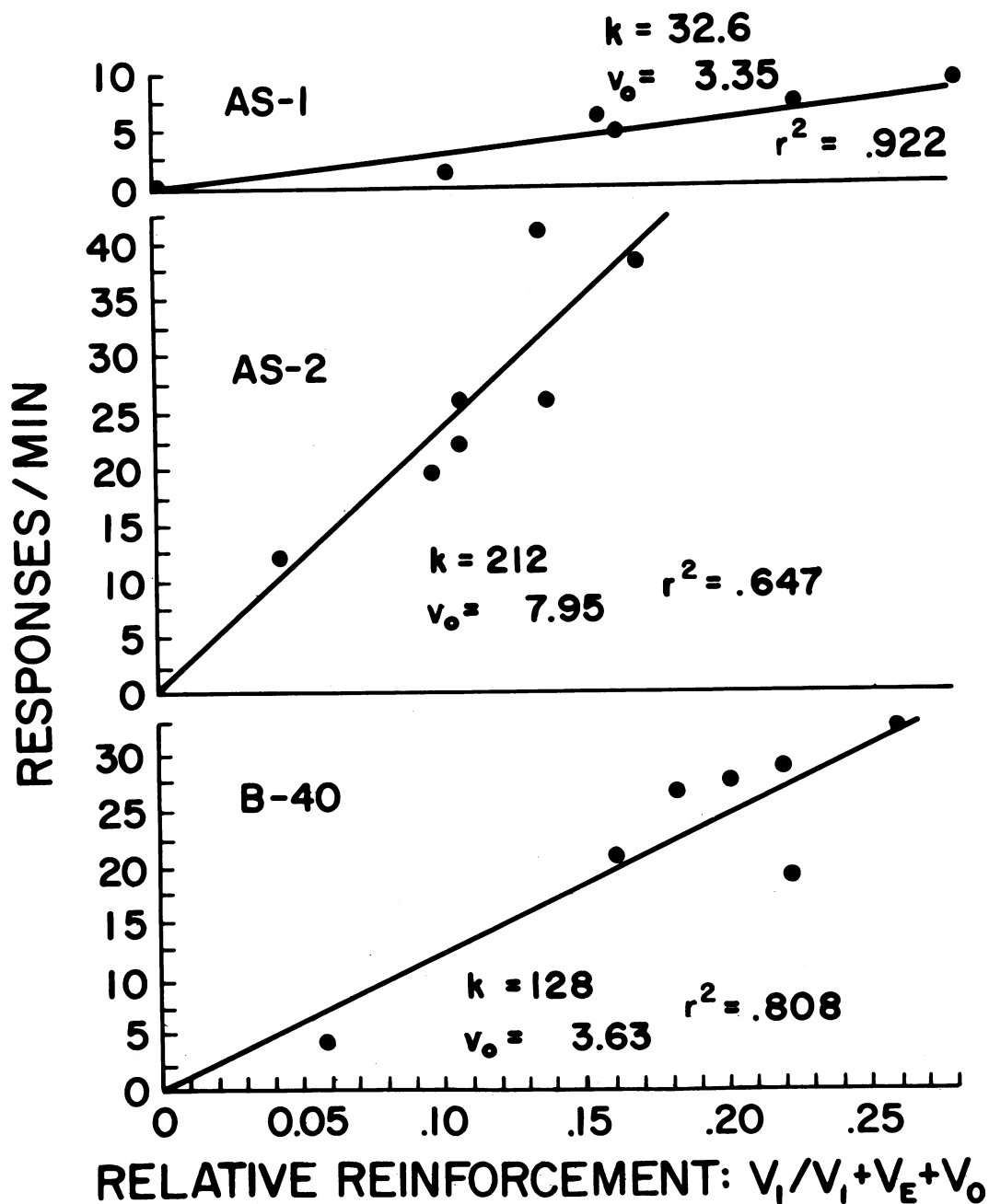


Fig. 3. Key pecks per min as a function of the proportion of reinforcement for key pecking to reinforcement from all causes.

response-contingent. This prediction, however, is contrary to previous findings (Lewis et al., 1974). The difference between Figure 3 and Figure 2 is in the fact that Figure 3 includes a  $V_0$  term and Figure 2 does not. From Figure 2 one can infer only that response rate is proportional to the proportion of total shock-

free periods that are response-contingent, at least for the range of values included in this experiment. If we include a source of variation that presumably is not directly under experimental control (specifically, in the  $V_0$  term in Figure 3), then predictions about absolute response rates, and not just relative

rates, become possible. The  $V_0$  term is thus directly comparable to Herrnstein's (1970)  $r_0$  term, which reflected a source of variation not directly attributable to experimenter-arranged reinforcers, such as cooing, preening, pacing, and so forth. Although the inclusion of an extra parameter in Figure 3 did not significantly increase the proportion of variance accounted for, there is a gain in the ease of interpretation of the equations. In addition, absolute rates can be predicted, which is not possible without the additional parameter ( $V_0$ ). This gain is at the cost of having to determine an additional parameter that is not independent of a subject's behavior.

Some theorists expect fundamental differences in the laws of learning for prepared and contraprepared responses (Seligman, 1970). In this experiment, pigeons pecked a key to avoid shock, a contraprepared response compared to, say, pigeons key pecking to produce food (Bolles, 1970). Nevertheless, key pecking maintained by negative reinforcement was influenced by added reinforcement in a manner similar to key pecking maintained by positive reinforcement (Rachlin & Baum, 1972). This finding implies that the distinction between prepared and contraprepared responses may not be necessary for the understanding of certain steady-state performances and that certain behavioral relationships are quite general.

The successful application of a common theoretical formulation (Herrnstein, 1970; Baum, 1973a) to both positive and negative reinforcement procedures suggests that the traditional distinction may not always be important theoretically. The qualifiers, positive and negative, may serve only to indicate the reason for one situation being more highly valued

than another, but may not be required to predict the influence of the reinforcer on behavior or the influence of added free reinforcers.

## REFERENCES

- Azrin, N. H. A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 161-163.
- Baum, W. M. The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 137-153. (a)
- Baum, W. M. Time allocation and negative reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 313-322. (b)
- Bolles, R. C. Species-specific defense reactions and avoidance behavior. *Psychological Review*, 1970, 77, 32-48.
- Gardner, E. T., & Lewis, P. Parameters affecting the maintenance of negatively reinforced key pecking. *Journal of the Experimental Analysis of Behavior*, 1977, in press.
- Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 243-266.
- Herrnstein, R. J., & Hineline, P. N. Negative reinforcement as shock frequency reduction. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 421-430.
- Lewis, P., Lewin, L., Stoyak, M., & Muehlheisen, P. Negatively reinforced key pecking. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 83-90.
- Rachlin, H., & Baum, W. M. Effects of alternative reinforcement: Does the source matter? *Journal of the Experimental Analysis of Behavior*, 1972, 18, 231-241.
- Seligman, M. E. P. On the generality of the laws of learning. *Psychological Review*, 1970, 77, 406-418.
- Sidman, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *Journal of Comparative and Physiological Psychology*, 1953, 46, 253-261.

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